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SPAT SETTLEMENT AND GROWTH ON A LONG-LINE CULTURE SYSTEM OF THE MUSSEL, *MYTILUS GALLOPROVINCIALIS*, IN THE SOUTHERN BLACK SEA

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Abstract

Spat settlement and growth at the depths of 3 and 7 m in a long-line mussel system in the southern Black Sea were determined in two seasons. The first spat collectors were hung in July 1997, the second in January 1998. Temperature, salinity, seston, particulate organic matter and chlorophyll-*a* were measured monthly. Depth had no significant effect on any of these parameters ($p>0.05$). There was a significant positive correlation between particulate organic matter and chlorophyll-*a* ($p<0.05$) at both depths. On the first collectors, most of the spat settled from October to January and on the second most settled in April-May 1998. The mean shell length, height, width and weight of the mussels from the first collectors were 32.11±0.68, 18.32, 11.76±0.35 mm and 3.40±0.22 g, respectively. Spat collectors were most efficient in February and March when heavy spat settlement occurred and predation and fouling were minimal. Growth performance of seeds was high due to the favorable environment. Recommendations for spat collection and cultivation are given.

Introduction

Marine aquaculture in the Black Sea is a relatively new activity. Though not yet widespread, fish and shellfish industries in many rural communities on the Black Sea coast appropriately use natural resources, create jobs and play a vital economic role. The Black Sea or Mediterranean mussel *Mytilus galloprovincialis* is probably the most important of the region's farmed species and is raised in almost all its littoral countries. In Turkey, mussels are cultured in the Marmara Sea but not in the Black Sea.

Most production phases involved in mussel farming are dependent on natural process-

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es. The collection of sufficient quantities of seed is an important factor in mussel farming all over the world and a better understanding of the distribution, abundance, seasonal fluctuation and factors affecting their settlement is essential for maximum utilization of seed resources (Appukuttan *et al*., 1989). Spat settlement, rapid growth and high survival are essential for mussel culture. Spat settle on a wide variety of filamentous substrates, including the byssal filaments of non-specific adults (Eyster and Pechenik, 1987), filamentous algae, fibrous ropes and mussel beds (Kiseleva, 1966; Davies, 1974; Petersen, 1984; Lane *et al*., 1985). Since 1980, a number of studies have assessed the endogenous and exogenous factors that affect the development and settlement of mytilid larvae (Bayne *et al*., 1983; Eyster and Pechenik, 1987). Among exogenous factors, temperature, salinity and food have received the greatest attention (Riisgard *et al*., 1980; Jespersen and Olsen, 1982; Manahan *et al*., 1983; Sprung, 1984). Artificial collectors, especially filamentous ones, are extremely effective for monitoring the settlement of mussel larvae under natural conditions and their absence tends to prolong the pediveliger stage of the larvae and contribute to a delay of metamorphosis.

Spat abundance, growth and survival differ between sites, even those located in very close proximity to each other in the same river inlet, bay, fjord, loch or coastal water (Mallet and Carver, 1989). Most of these differences are induced by environmental variables, namely salinity, exposure to air, temperature and food availability (Dickie *et al*., 1984; Karayücel and Karayücel, 1998, 1999).

There is a lack of knowledge regarding culture of *M. galloprovincialis* in the Black Sea. Ecological problems of mussel culture were studied by Ivanov (1990). Meroplankton of the Black Sea and seasonal dynamics of mussel larvae at an experimental marine farm were studied by Murina *et al*. (1990). Ivanov and Bulatov (1990) investigated genetic populations of Black Sea *M. galloprovincialis*.

The aims of the present study were to determine the season, duration and density of spat settlement, study the effects of depth, temperature, seston, particulate organic matter (POM) and chlorophyll-*a* on seed growth, examine the use of polypropylene rope as a spat collector and investigate fouling and predation from the early development stages to the stage in which spat are large enough to be used as seed in a long-line mussel culture system.

Materials and Methods

The experiment was carried out in the southern Black Sea near Sinop, Turkey, from July 1997 to June 1998. The long-line system (Fig. 1) consisted of a 30 m head rope, maintained at 1.5 m below the water surface by floats and buoys. Spat collectors (polypropylene ropes with a diameter of 16 mm and length of 7 m) were suspended from the head rope. Wooden pegs of 25 cm were attached to the collectors at 30-40 cm intervals to prevent the slide of mussels. Weights of 2-2.5 kg were attached to the ropes to stabilize them against wave action.

The collectors were suspended from the long-line in two seasons to determine the onset and duration of spat settlement and study fouling organisms and predators at the depths of 3 m and 7 m in each season. In the first stage, 20 collectors were hung in July 1997 and in the second stage, seven collectors were hung in January 1998. Both experiments continued until June 1998.

Temperature was measured monthly at both depths. Salinity did not differ between 3 and 7 m; therefore, monthly salinity samples were taken only from the depth of 3 m. To analyze seston, POM and chlorophyll-*a*, 2-l water samples were taken in duplicate from each depth each month using Nansen type sampling bottles. The water was sieved through a 150-µm nylon mesh to remove large particles and zooplankton. Amounts of seston, POM and chlorophyll-*a* were determined according to Stirling (1985).

Spat were collected and growth was analyzed during a ten-month period. To determine spat density, triplicate spat samples (one from each of three collectors) were taken at monthly intervals from each depth. To pre-

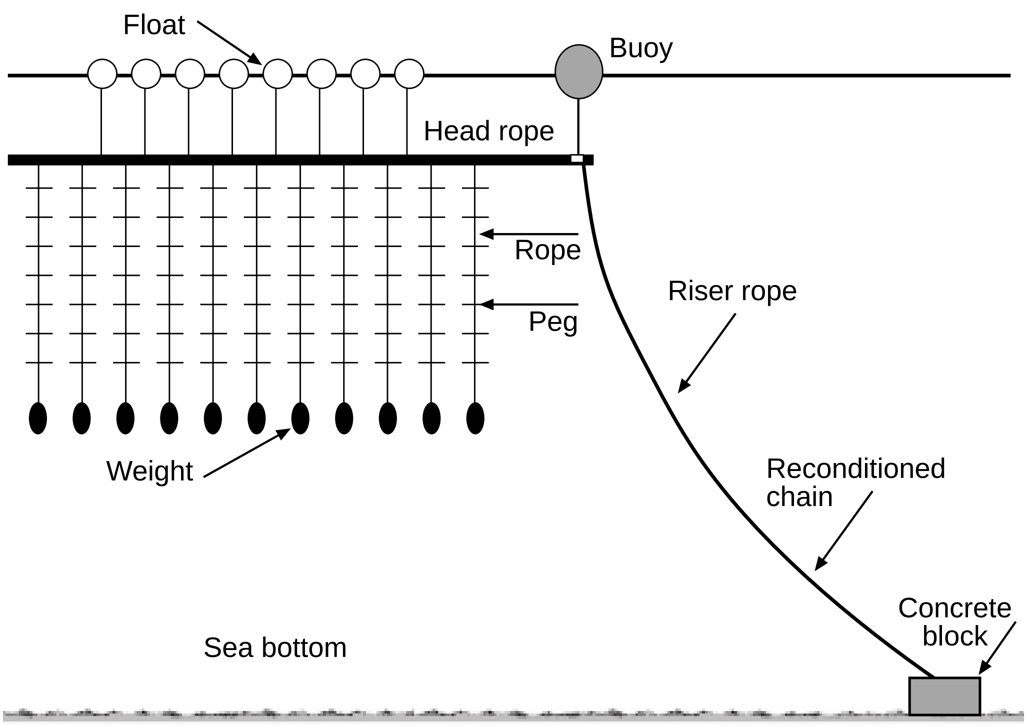

Fig. 1. The long-line system for culturing mussels (not to scale).

vent loss of spat, the collector ropes were lifted gently and the spat were removed from 25 cm of each rope into a 25-l tank filled with sea water. The spat were transferred from the tank to 5-l plastic receptacles, pre-marked and filled with sea water, placed inside a container and transferred to the laboratory. Spat were counted in Petri dishes under a stereomicroscope. Shell length was determined by measuring the maximum anterior-posterior axis to the nearest 0.1 mm. Live weight was measured by blotting animals with tissue paper and measuring them with their shells closed to the nearest 0.01 or 0.001 g, according to spat size. Newly settled spat were identified by size (they were less than 2 mm) and growth rate, known from earlier observations (Karayucel, 1996; Karayucel and Karayucel, 2001). After counting the spat, 150-200 were taken by a sub-sampling method for biometric measurements (Quayle and Newkirk, 1989).

Predation and fouling were determined after barnacles, seaweeds, etc., were cleaned from the mussels.

Specific growth rate (SGR%) was calculated according to Chatterji *et al*. (1984). Relationships between environmental factors were tested by correlation matrix, using Minitab computer software. Differences in environmental factors were tested by Students *t* test. Differences in spat growth and density between the depths of 3 m and 7 m were tested by ANOVA, using Minitab computer software.

Results

Water temperature, salinity, seston, POM and chlorophyll-*a* values are given in Table 1. The seasonal temperature cycles at 3 and 7 m were very similar. Maximum values were recorded in June and minimum values in February and March. Salinity was around 16‰ from September to December. It dropped to

Table 1. Values (±SE) of environmental factors at depths of 3 m and 7 m, from July 1997 to June 1998, in the southern Black Sea.

Parameter		*3 m*	*7 m*
Temperature (ºC)	Minimum	7.1	7.3
	Maximum	22.1	22.1
	Mean	13.65±1.8	13.5±1.7
Salinity (ppt)	Minimum	14.1	-
	Maximum	16.1	-
	Mean	14.92±0.91	-
Seston (mg/l)	Minimum	1.9	2.3
	Maximum	13.6	12.3
	Mean	5.91±1.2	5.47±1.0
Particulate organic matter (mg/l)	Minimum	0.9	1.0
	Maximum	6.1	6.5
	Mean	2.76±0.56	2.66±0.57
Chlorophyll-*a* (µg/l)	Minimum	0.35	0.35
	Maximum	21.99	24.98
	Mean	3.78±2.1	4.51±2.6

14.5‰ in January and remained relatively stable until June. Seston, POM and chlorophyll-*a* were highest in March and dropped from March to June (Fig.2). In general, they were high during the spring and low during autumn and winter, with the lowest values in September and October. The relationships between seston, POM and chlorophyll-*a* are given in Table 2. There was a significant positive relationship between seston, POM and chlorophyll-*a* ($p<0.05$) at both depths. Depth had no significant effect on temperature, seston, POM or chlorophyll-*a* ($p>0.05$).

In the first experiment, barnacles settled on the collectors after their planktonic stages and continued to develop throughout the summer and autumn. Spat settlement began on sea algae in August and were first counted in September. The monthly spat density is shown in Fig. 3. Spat settled from the water surface downward and density was significantly higher at 3 m than at 7 m ($p<0.05$). In August and September, barnacles (*Balanus balanoides* L.) covering about 60-70% of the available surface area of the ropes competed with the spat for growing area. The amount of barnacles decreased with depth.

In the second experiment, settlements of barnacles were not observed on the spat collectors until April. Spat settlement also began in April. High quality, uniform and free of fouling spat settlements were observed in April and May. Spat density reached its maximum of 19,760±38 individuals per m at 3 m in May,

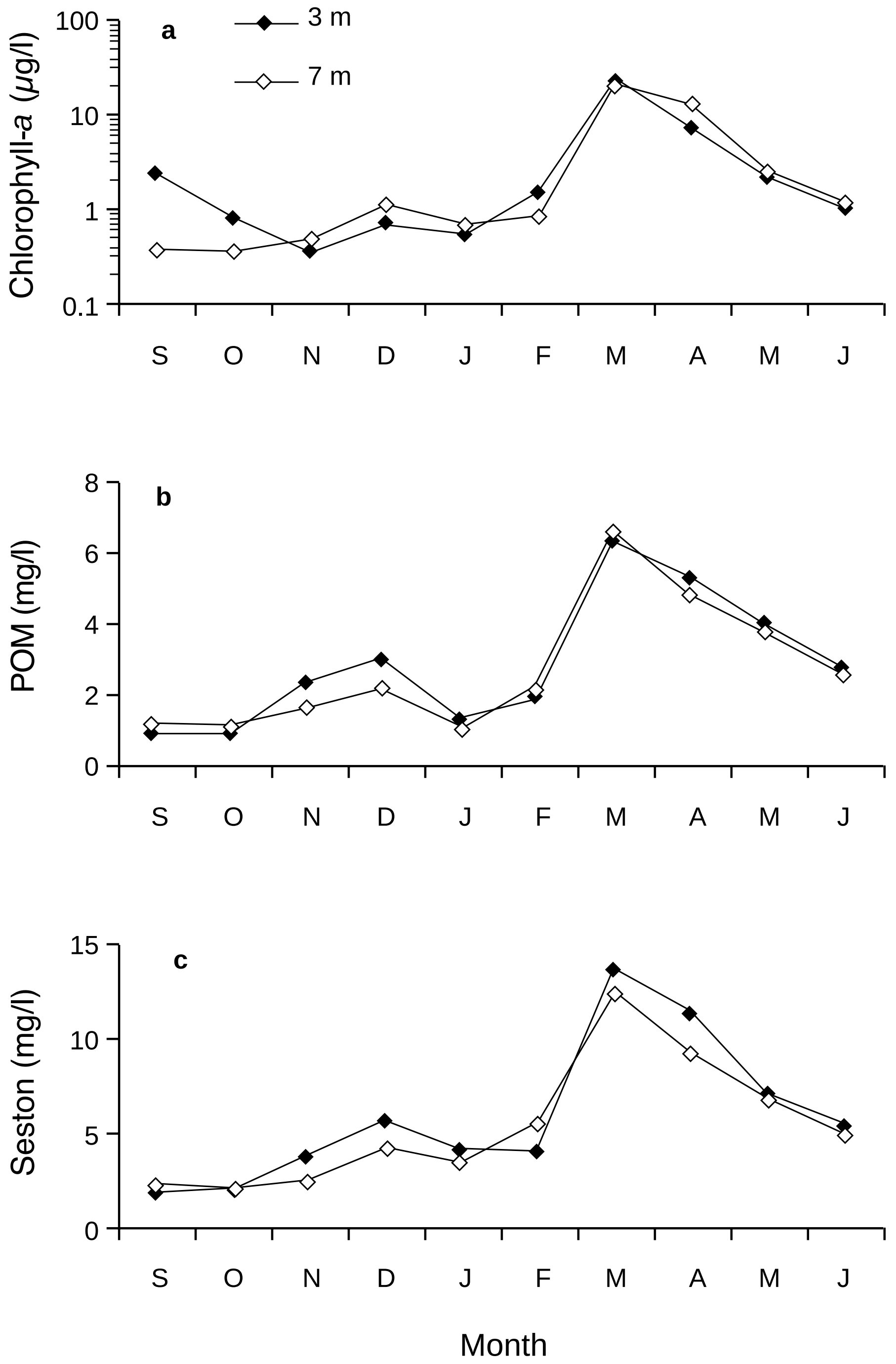

Fig. 2. Monthly values of (a) chlorophyll-*a,* (b) particulate organic matter and (c) seston at depths of 3 and 7 m in the southern Black Sea.

Table 2. Relationship between chlorophyll-*a*, particulate organic matter (POM) and seston.

Regression equation	*F*	*r*
Chlorophyll-*a* = -5.32 + 3.48 POM	30.38	0.728
Chlorophyll-*a* = -5.97 + 1.72 seston	30.48	0.726
POM = -0.11 + 0.48 seston	166.83	0.938

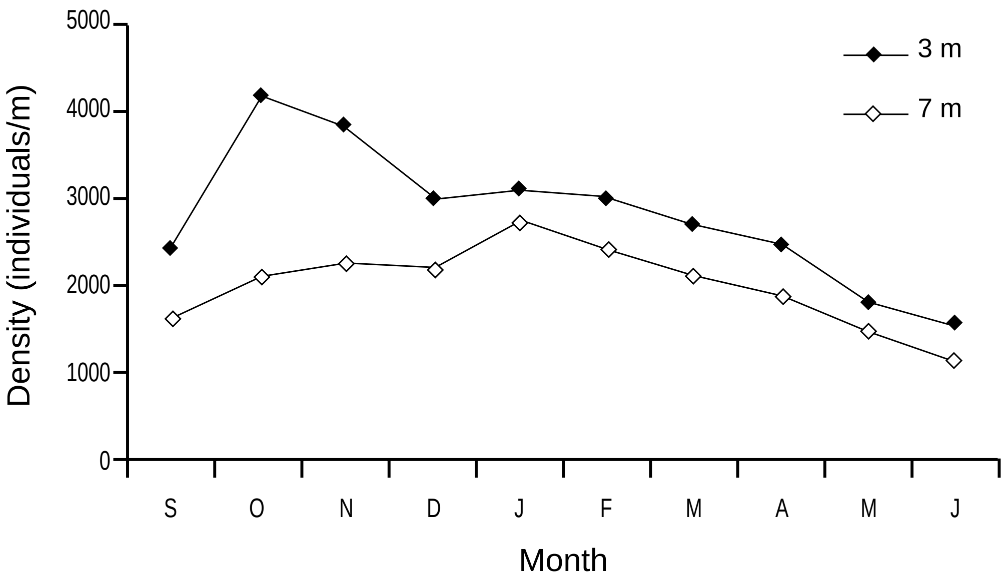

Fig. 3. Monthly mean spat density on collectors suspended from a long-line in July.

then dropped to 15,187±44 individuals per m in June. Newly settled spat were rounder and brighter than older spat.

Spat were first measured in September. Length frequencies of spat for January and June are shown in Fig. 4. Shell growth, live weight and SGR% are given in Fig. 5. At both depths, about 70% of the shell growth occurred between March and June when more food was available. At the end of ten months, spat at 7 m were 32.11±0.68 mm length, 3.40±0.22 g weight, 18.32±0.39 mm height and 11.76±0.35 mm width. Spat at 3 m were 35.59±0.66 mm length, 4.36±0.24 g weight, 19.89±0.36 mm height and 12.84±0.25 mm width. Mean monthly SGR% was 25.43%±7.16 at 3 m and 24.07%±4.86 at 7 m. Shell length, live weight and SGR% did not differ significantly between the two depths. There was a positive relationship between SGR% and chlorophyll-*a*. POM and seston positively correlated with shell length and live weight ($p<0.05$).

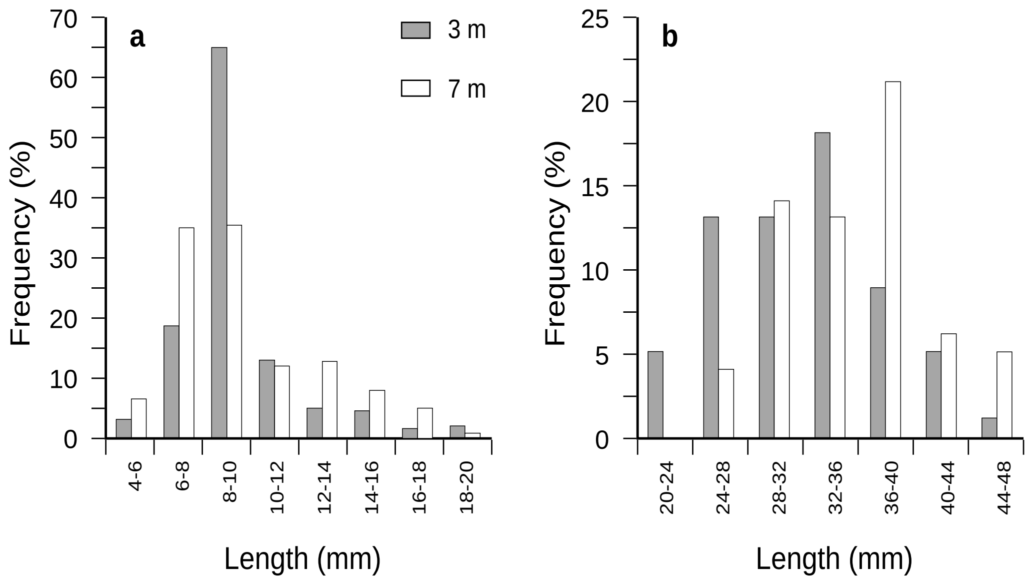

Fig. 4. Lengths of spat settled on ropes at depths of 3 and 7 m in (a) January and (b) June.

Discussion

Seston, POM and chlorophyll-*a* are related to algal bloom. When water temperature is above10ºC and food is available, spat growth is high. Mussel growth is influenced by many factors, such as temperature, food intake, tidal exposure, waves, currents, salinity and population density (Bayne, 1976). When experimental conditions are less than optimal and suitable surfaces are insufficient, it is not unusual that planktonic life extends beyond two months (Bayne, 1976). The pelagic life of *Mytilus* larvae can be prolonged by more than six months when growth and metamorphosis are delayed (Lane *et al*., 1985). In the present study, most of the spat settled between April and December but some spat settled during the rest of the year. Already in August, there were high numbers of barnacles on the spat collectors hung in July. In April, however, there were no barnacles on the collectors hung in January, showing that barnacles settle heavily in summer when they are in their meroplanktonic stage. *Mytilus* larvae attach readily to filamentous substrates such as bryozoans, hydroids and filiform algae (Eyster and Pechenik, 1987). Seed growth was strongly influenced by barnacle settlement.

Due to the high amount of food during the spring, there was a clear seasonal influence on shell growth with a pronounced peak during March-June. After ten months, our results, in terms of mean shell length, were better than those obtained in Scotland's west coast sea lochs because of the high food rate and temperature (Karayücel, 1996; Karayücel and Karayücel, 2001).

In the Black Sea, mussel larvae have two peak times. The first peak occurs in early spring and the second in autumn. In winter, the number of larvae decreases but seed are available year-round (Murina *et al.*, 1990). This finding supports our results. At 3 m, spat settlement peaked in October and decreased afterward. At 7 m, the density continued to rise from October through January, and then dropped. This can be explained. Mussel larvae begin to settle on the ropes near the surface because of the high temperature, abun-

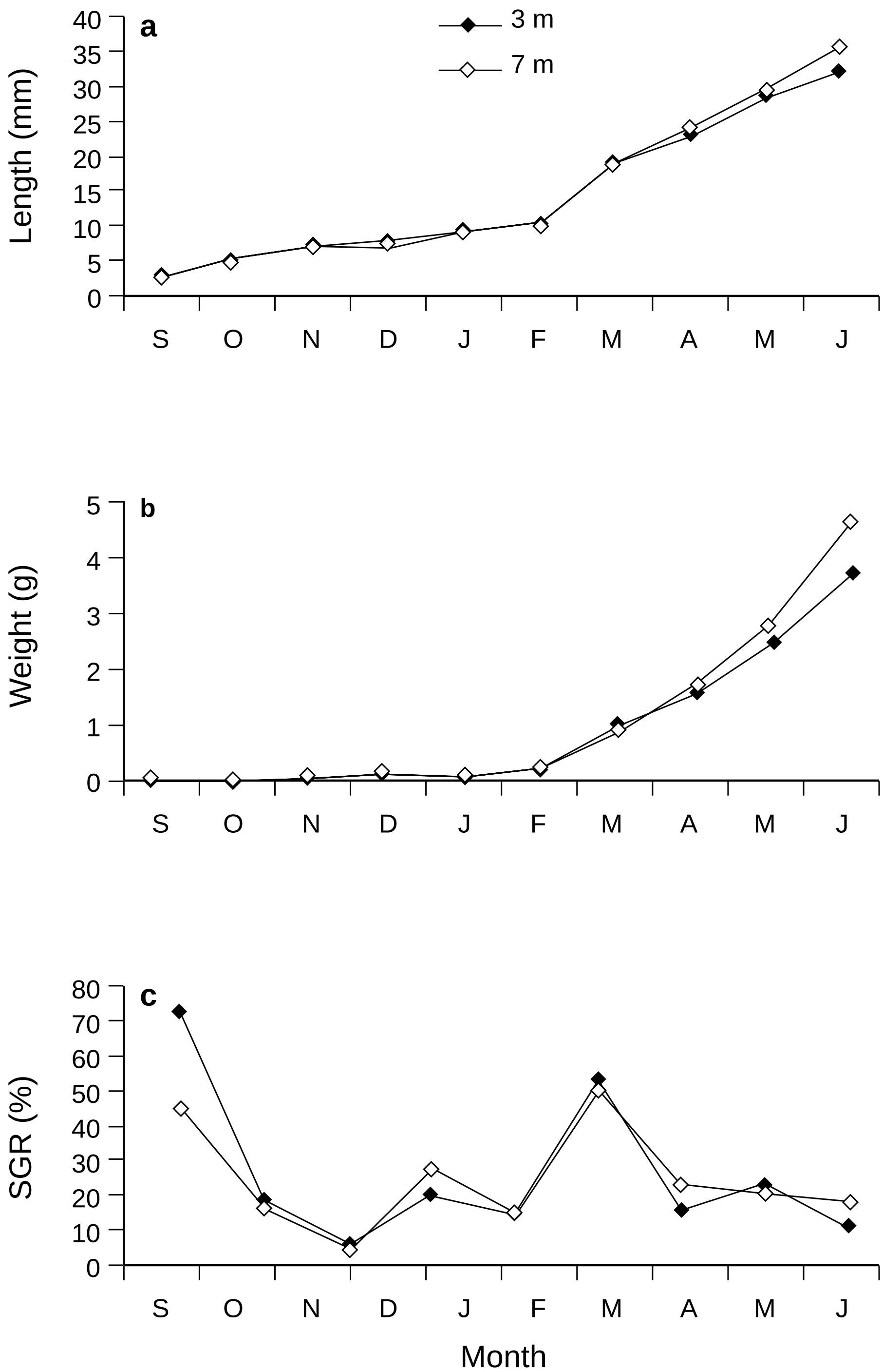

Fig. 5. Shell length (a), live weight (b) and specific growth rate (c; SGR) of spat, by month.

dance of light and available food. When the settling area becomes filled, they prefer to settle more deeply rather than on bigger (earlier) mussels. Therefore, the seed density was higher at 3 m than at 7 m in October. Afterward, the density at 3 m dropped due to losses, mortality and predation, while at 7 m the density continued to rise until January, most probably due to the higher temperature in the deeper water. Spats preferred the ropes suspended in January. Therefore, there were high quality and uniform spat settlements in the second experiment in April-May.

Apparently, a seed density of over 1,200 individuals per m is necessary to produce high yields of cultured mussels (Okumus, 1993). Okumus (1993) reported 1,950 individuals per m in Loch Etive and 21,100 individuals per m in Loch Leven on the west coast of Scotland. Dare and Davies (1975) studied settlement on ropes made of coir (the rough outer hair-like covering of coconut) and reported on 17,000-28,000 individuals per m in Wales. Mason and Drinkwater (1981) found higher spat settlement on coir ropes than on polypropylene and sisal ropes, but settlement even on coir ropes appeared to be very poor (3,300-6,600 individuals per m). Extremely high densities may limit growth due to overcrowding and competition for available food.

Upper levels of water are preferred for settlement (Sutterlin *et al*., 1981; Farias, 1991). This finding is supported by our results. Our results also showed that spat can be collected efficiently on 16 mm diameter polypropylene ropes and that collectors should preferably be installed in January or February. When placed later in spring and summer, barnacles settled on the spat collectors and competed with them for food and space.

References

Appukuttan K.K., Nair T.P. and K.T. Thomas, 1989. Spat settlement of brown mussel *Perna indica* Kuriakose and Nair in the southwest coast of India. *J. Mar. Biol. Assoc. India*, 31:266-275.

Bayne, 1976. *Marine Mussels: Their Ecology and Physiology*. Cambridge Univ. Press, Cambridge, UK. 506 pp.

Bayne B.L., Salkeld P.N. and C.M. Worral, 1983. Reproductive effort and value in different populations of the mussels, *Mytilus edulis* L. *Ecologia*, 59:18-26.

Chatterji A., Ansari Z.A., Ingole B.S. and A.H. Parulekar, 1984. Growth of green mussel, *Perna viridis* L., in a seawater circulation system. *Aquaculture,* 40:47-55.

Dare P.J. and G. Davies, 1975. Experimental suspended culture of mussels, *Mytilus edulis* (L.), in Wales using spat transplanted from a distant settlement ground. *Aquaculture*, 6:257-274.

Davies G., 1974. A method for monitoring the spat fall of mussel (*Mytilus edulis* L.). *J. Con. Int. Exp. Mer.,* 36:27-34.

Dickie L.M., Boudreau P.R. and K.R. Freeman, 1984. Influence of stock and site on growth and mortality in blue mussels, *Mytilus edulis. Can. J. Fish. Aquat*. *Sci.*, 41:134-141.

Eyster L.S. and J.A. Pechenik, 1987. Attachment of *Mytilus edulis* L. larvae on algal and byssal filaments in enhanced water agitation. *J. Exp. Mar. Biol*., 114:99-110.

Farias S.J.A., 1991. Ecology, culture and utilisation of the mussel, *Brachidontes recurvus* (Rafinesque), in the context of an integrated management approach to Boca Del Rio-Mandinga estuarine system, Veracruz, Mexico. Ph.D. thesis, Univ. Stirling. 234 pp.

Ivanov V.N., 1990. Ecological problems of mussel mariculture at the Black Sea. *Hydrores,* 7(8):75-77.

Ivanov V.N. and K.V. Bulatov, 1990. Population genetic investigations of Black Sea *Mytilus galloprovincialis* Lam. *Hydrores,* 7(8): 106-111.

Jespersen H. and K. Olsen, 1982. Bioenergetics in veliger larvae of *Mytilus edulis* L. *Ophelia,* 21:101-113.

Karayücel S., 1996. Influence of environmental factors on spat collection and mussel (*Mytilus edulis* L.) culture in raft system in two Scottish sea lochs. Univ. Stirling. 297 pp.

Karayücel S. and I. Karayücel, 1998. Estimating the carrying capacity of mussel raft systems in two Scottish sea lochs. *Israeli J. Aquacult. - Bamidgeh*, 50(1):12-19.

Karayücel S. and I. Karayücel, 1999. Growth, production and biomass in raft cultivated blue mussels *(Mytilus edulis* L.) in two

Scottish sea lochs. *Israeli J. Aquacult. - Bamidgeh*, 51(1):65-73.

Karayücel S and I. Karayücel, 2001. Spat collecting, growth and associated problems in mussel (*Mytilus edulis* L.) in two Scottish sea lochs. *Turkish J. Mar. Sci.,* 7:195-205.

Kiseleva G.A., 1966. Factors stimulating larval metamorphosis of the lamellibranch *Brachodentes lineatus* (Gmelin). *Zool. Zhurnal.,* 45:1571-1573.

Lane D.J.W., Beamont A.R. and J.R. Hunter, 1985. Byssus drifting and the drifting treads of the young post-larval mussel *Mytilus edulis*. *Mar. Biol*., 84:301-308.

Mallet A.L. and C.E.A. Carver, 1989. Growth, mortality and secondary production in natural populations of the blue mussel *Mytilus edulis* L. *Can. J. Aquat. Sci*., 46:1154-1159.

Manahan D.T., Wright S.J. and G.C. Stephens, 1983. Simultaneous determination of net uptake of 16 amino acids by a marine bivalve. *Am. J. Physiol.*, 244:832-838.

Mason J. and J. Drinkwater, 1981. *Experiment on Suspended Cultivation on Mussels in Scotland*. Scot. Fish. Int. Pamphlet 4. DASF, Aberdeen. 15 pp.

Murina V.V., Artemjeva Ya N., and I.I. Kazankova, 1990. Meroplankton of the Black Sea and seasonal dynamics of mussel larvae at experimental marifarm region. *Hydrores,* 7(8):112-117.

Okumus I., 1993. Evaluation of suspended mussel (*Mytilus edulis* L.) culture and integrated experimental mariculture (salmon-mussel) trials in Scottish sea lochs. Ph.D. thesis, Univ. Stirling. 336 pp.

Petersen J.H., 1984. Establishment of mussel bed: attachment behaviour and distribution of recently settled mussels *Mytilus edulis* L. *Veliger*, 27:7-13.

Quayle D.B. and G.F. Newkirk, 1989. *Farming Bivalve Molluscs: Methods for Study and Development.* World Aquacult. Soc. and Int. Dev. Res. Centre. 294 pp.

Riisgard H.U., Randlov A. and P.S. Kristensen, 1980. Rates of water processing, oxygen consumption and efficiency of particle retention in veligers and young post-metamorphic *Mytilus edulis*. *Ophelia*, 19:37-47.

Sprung M., 1984. Physiological energetics of mussel larvae (*Mytilus edulis*). I. Shell growth and biomass. *Mar. Ecol. Prog. Ser.*, 17:283-293.

Stirling H.P., 1985. *Chemical and Biological Methods of Water Analyses for Aquaculturist*. Inst. Aquacult., Univ. Stirling. 119 pp.

Sutterlin A., Aggett D., Couturier C., Scaplen R. and D. Idler, 1981. *Mussel Culture in Newfoundland Waters*. Mar. Sci. Res. Lab. Tec. Rep., 23. Newfoundland. 82 pp.